10/031957

531 R d PCT/PT 22 JAN 2002

SUBSTITUTE SPECIFICATION

Title: METHOD FOR PRODUCING A TORSION SPRING

Inventors: Maik Wiemer
Karla Hiller
Detlef Billep
Uwe Breng
Bruno Ryrko
Eberhard Handrich

BACKGROUND

Field of the Invention

The present invention relates to methods for producing a torsion spring for [as a part of] a micromechanical torsion spring/mass system. More particularly, the invention pertains to the production of a torsion spring [which can be produced] from two wafers or [two] wafer composites that possesses [and have a] low torsional relative to [stiffness compared to the] transverse stiffness in the lateral and vertical directions.

Description of the Prior Art

Silicon torsion springs [in microstructuring] are [already] known in various design variants in microstructuring. For example, C. Kaufman, J. Markert, T. Werner, T. Gessner and W. Dötzel in "Characterization of Material and Structure Defects on Micromechanical Scanners by Means of Frequency Analysis" Proceedings of Micro Materials (1995) p. 443, describe [the specialist relatively long narrow strips, for example, for the

article in literature reference[1] describes]

articulated mounting of torsion mirrors. The spring cross section is of trapezoidal shape. [The] Springs are formed on opposite wafer edges and [are] produced by etching pits from the back surface during structuring of the springs from the front surface. J. Choi, K. Minami and M. Esahi in "Silicon Angular Rate Sensor by Deep Reactive Ion Etching," Proceedings of the International Symposium on Microsystems, Intelligent Materials and Robots (Sendai, Japan, 1995), pages 29 through 32, propose [Literature reference [2] describes] the production of a rectangular torsion cross section, in particular for suspending a tuning fork resonator, with a relatively high aspect ratio (height:width ratio ≥ 4) by deep RIE (reactive ion etching) [being proposed as the production method]. The [These] two torsion spring cross sections have the disadvantage [drawback] of sensitivity [also being sensitive] to transverse stresses. The spring cross-section produced by [using] the first method is particularly sensitive to vertical bending, while the spring cross section produced by [using] the second method is particularly sensitive to lateral bending.

German patent document DE 28 18 106 A1 discloses a torsion spring [which, on account] of [a] cross-shaped cross-section that has [a] low torsional [a] compared to [the] transverse rigidity in the lateral and [rigidity] vertical directions. A tube for a sensor that also acts as a torsion spring is disclosed in the Journal

of Microelectromechanical Systems, Vol. 6, No. 2 (June 1997) at pages 119 through 125 [discloses a tube of a sensor which also acts as a torsion spring]. The [This] tube is produced using the Coriolis principle, by turning wafers, placing them against one another in a mirror-symmetrical manner and bonding them, in each case with a trench formed therein.

In [As] a further [example of an] application of such torsion springs, rotary mirrors and micromechanical rotation rate sensors are mentioned [pointed out] in International patent publication [application] WO 96/38710. In particular, Figure 8 of that [this] document illustrates [shows] a double-layer vibratory structure that [which] is held in a frame by [means of] a cross-shaped spring joint formed from the wafer layers. This cross-shaped spring joint, which is formed from a total of four individual spring elements, improves [the desired] stiffness in the wafer levels, a [to which] fact referred to [reference is made] in the patent publication [above-mentioned WO document]. For a vibratory structure of this type, in which the vibrators, [of which are] arranged in plate form above one another, form a micromechanical rotation rate sensor based on the Coriolis principle, [however,] it is desirable to optimize the [said] cross-shaped spring joint [, specifically] in such a way that transverse stiffness relative [compared] to [the] torsional stiffness [which] is as high as possible in the direction of the wafer planes and perpendicular thereto [,] (i.e. in the lateral and vertical directions) [, results].

SUMMARY AND OBJECTS OF THE INVENTION

It is therefore the object of the invention to provide a method for producing an optimized torsion spring for a micromechanical torsion spring/mass system.

The invention addresses the above object by providing a method for producing a torsion spring with low torsional compared to transverse stiffness in the lateral and vertical directions, as part of a micromechanical torsion spring/mass system from two wafers or wafer composites. Such method is begun by producing a spring extending over the entire thickness of the wafer or wafer composite by anisotropic wet chemical etching. The spring has a V-shaped cross section that is laterally delimited by [111] planes on at least one side edge region of each wafer or wafer composite.

The method then continues by rotating the two wafers or wafer composites through 180°. Finally, the two wafers or wafer composites are joined to one another, for example by bonding, while oriented with respect to one another in a mirror-image fashion so that an overall x-shaped torsion of the two V-shaped spring cross sections.

The foregoing and other features of the

invention will become further apparent from the detailed description that follows. Such description is accompanied by a set of drawing figures. Numerals of the drawing figures, corresponding to those of the written description, point to the features of the invention with like numerals referring to like features throughout both the written description and the drawing figures.

[The invention is explained in more detail below with reference to two exemplary embodiments, in which:]

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 illustrates [shows] a first method in accordance with [variant according to] the invention for producing a torsion spring with an X-shaped cross-section [from two wafers]; and

Figure 2 illustrates [shows] a second method in accordance with the invention for producing a torsion spring with an X-shaped cross-section [modified procedure].

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Figure 1 illustrates a first method in accordance with the invention for producing a torsion spring with an X-shaped cross section from two wafers. In [the case of] Figure 1, the starting point for the [production] method is two identical wafers, while in [the case of] Figure 2, which illustrates a second method in accordance with the invention, the

starting point for the [production] method is two wafer layer composites, [which are] separated [from one another] or electrically insulated from one another along their common surface plane by an insulating layer 1 [having a layer thickness of, for example, up to 4 um]. Strip-shaped etching masks 2 are applied in the lateral edge region of the wafers or [of] the wafer composites. [Then] A spring 3 with a V-shaped cross section, which is laterally delimited by [111] planes, is then produced in the edge region of each wafer or wafer composite by anisotropic, wet-chemical etching. [Then,] Two of the wafers or wafer composites which have been prepared with a V-shaped spring in this way are rotated through 180° with respect to one another and are then joined [bonded] to one another oriented mirror image symmetrically with respect to one another. The joint process may be employed [, in particular by silicon direct bonding] so that the desired transversely rigid torsion spring of [which is] X-shaped [is] cross section is formed [,] as a suspension element for a uniform torsion spring/mass system structure.

If the invention is used in combination with the production of micromechanical rotation rate sensors, the basis used ([in order] to be able to release different excitation potentials or reset signals, on the one hand, and feed and readout potentials, on the other hand, to the outside) is preferably a two-layered wafer composite for [in] each [case one] of the plate-type oscillators. [In order, for example,] To be able to supply or remove

four different electrical potentials by the crossed springs [of the torsion springs produced using the method according to the invention], it is advantageous for an insulating oxide to be formed on the surface of at least one of the wafers or the wafer composite [on that surface which] that faces the other wafer or the other wafer composite during bonding.

The X-shaped, integrally joined torsion spring cross section [which is] formed by [as a result of] the method increases the ratio of transverse stiffness to torsional stiffness as opposed [compared] to a rectangular cross section and also as [, but also] compared to individual crossed spring elements, as described [are shown] in [the abovementioned] WO 96/38710, by more than two orders of magnitude.

A particular advantage of the method of [according to] the invention resides in its [the] simple technology. [since] The torsion spring is not affected [influenced] by [the] time-dependent etching processes. As a result [so that overall] Only one etching step takes place that [which] is critical in terms of time duration in the overall assembly of the two V-shaped springs [takes place].

The dimensional accuracy of the torsion spring, the masks of which obviously include long, narrow structures, is dependent, inter alia, upon [on] precise matching of [between] the crystal direction [110] [and the respective] to mask orientation. To insure [that this is achieved in the invention, for] precise orientation of the wafers

with respect to one another and/or of wafers with respect to masks, the setting reference for the joint process, in particular silicon direct bonding, and the lithography is oriented in the [110] crystal direction using suitable chemical, plasma-chemical and/or mechanical means. This orientation may, for example, be affected by initially providing the wafers with an etching mask which is produced parallel to the ground bevel of a mask edge. [then] The wafers are then anisotropically overetched using this mask, [with the result that] resulting in the formation of a new reference bevel [is formed], which then serves as an optical or mechanical (preferably gravity-assisted adjustment) reference for the joint process and the lithography, i.e. the mask orientation.

While this invention has been described with reference to its presently-preferred embodiment, it is not limited thereto. Rather, the invention is limited only insofar as it is described by the following set of patent claims and includes within its scope all equivalents thereof.